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(54) IMPROVEMENTS IN AND RELATING TO A LASER BEAM APPARATUS

(71) I, DAVID SCIAKY, a citizen of the United States of America, of 999 No. Lake Shore Drive, Chicago, Illinois 60611, United States of America,

do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a laser beam apparatus for working materials by focusing a laser beam at a desired point at or near the workpiece in order to cause the energy in the beam to weld, cut, pierce or heat treat the work. More specifically, the invention relates to apparatus with which large workpieces of irregular shape and height may be continuously worked.

In the past, metal sheets as thick as .020 inches have been worked successfully by the laser beam and mainly by means of pulsed beams generated in a ruby or neodymium glass laser. The power derived from these lasers is generated in the form of high power pulses which are directed to the spot to be worked to effect a machining or welding operation but because the average power of these devices is limited, their use has been restricted to applications in which other means could not conveniently be used. The welding or cutting rate when using this type of laser is extremely slow since the machining operation cannot proceed on a continuous basis.

Recently new types of laser devices have been developed which are capable of generating coherent radiation at extremely high powers, for example CO_2 laser devices capable of generating a 10 kilowatt beam at a wave length of 10.6 microns. With a laser of this type, and with suitable work handling and laser beam focusing equipment, it is now possible to weld 12.6 mm stainless steel at a speed of 660 mm per minute and 6.3 mm thick stainless steel at a rate of 2540 mm per minute. With this same laser power 12.6 mm thick Inconel 718 (Registered Trade Mark) was cut at a rate of 15 mm per minute.

Because of the extremely high power density in the laser beam, especially in the area where the beam is focused at or near the work, it is essential that means be provided on the laser machining device to protect the operator from injury from laser burn by effectively shielding the laser beam so that it may not be intercepted by any part of the operator's body. Furthermore, since the work to be welded or machined may be irregular in shape and height, it is necessary to provide a means for following the seam to be welded or cut and to provide means for focusing the laser continuously so that the focal point follows any irregularities in the height of the parts being worked.

It is an object of this invention to provide a means for preventing a body from intersecting the laser beam on its path from the laser generator to a workpiece.

According to one aspect of this invention laser beam apparatus comprises lens means for focusing the laser beam, means for sensing the relative position of the lens means and the surface of a workpiece which, in use, is disposed in the path of the beam, means actuable by the sensing means to move the lens means and the surface of the workpiece relative to one another into a desired relative position and thereby to maintain the focus of the beam in a desired position relative to the workpiece, and means for preventing interception of the beam other than by the workpiece.

According to another aspect of this invention laser beam apparatus comprises means for generating a laser beam, lens means for focusing the beam, means for moving the beam and a workpiece, which, in use, is disposed in the path of the beam, relative to one another to traverse the beam over the surface of the workpiece, control means for maintaining the surface of the workpiece and the lens means a predeter-

mined distance apart and thereby to maintain the focus of the beam in a desired position relative to the workpiece and means for preventing interception of the beam other than by the workpiece.

The means for preventing interception of the beam other than by the workpiece preferably comprises a shield surrounding the beam and variable in length.

By automatically adjusting the focus of the beam to a predetermined point in relation to the surface of the work being machined and controlling the shield to act in conjunction with the automatic focusing, a complete shielding over the throw of the laser beam is provided, irrespective of variations in height or shape of the parts being machined.

The apparatus may include means for interrupting the laser beam when the means for preventing interception of the beam other than by the workpiece, is displaced from its normal position or damaged.

In one form means are provided for measuring changes in height and shape of the part being machined and causing this measurement to effect changes in the focal length by means of a servo-mechanism controlled by the voltage analogue of the measurements. The measurements may also be used to continuously control the configuration or length of the shield.

Preferably, the shield comprises an assembly of telescoping tubes and which includes means for automatically adjusting the overall length of said tube assembly in proportion to the variation in distance between the lens and the workpiece surface.

An embodiment of this invention will now be described by way of example with reference to the accompanying drawings, of which:—

Figure 1 is a perspective view of a laser beam apparatus;

Figure 2 shows a means for shielding the laser beam;

Figure 3 is a block diagram of a feedback control system which may be used to operate the beam protective device and laser focusing lens system;

Figure 4 is a schematic plan view of another laser beam transmission arrangement;

Figure 5 illustrates an embodiment wherein the telescope is mounted vertically; and

Figure 5A illustrates a way of mounting the laser beam shield on the telescope.

In Figure 1 the laser beam 1 which is generated by the laser beam source 2 is projected from the laser source by means of three flat water-cooled mirrors 3, 4 and 5, so that it passes through the centre of the movable telescope structure 6. The focused beam emerges from the telescope 6 and is directed to a workpiece which may be supported vertically in the path of the beam. Alternatively, the beam may be deflected downward by a mirror 7, focussed and projected onto the workpiece 14 mounted upon platen or table 15 as shown in Figure 1. In order to focus the beam upon the workpieces which may be irregular in shape and may be at different heights from the surface of the table 15, the telescope 6 which is supported on a track 17 by means of slides 16, is utilized. The telescope 6 may be positioned by means of a ball screw 8 driven by motor 9 and a nut mounted upon the slide 16 with great accuracy anywhere along the track 17 so as to focus the laser beam at any desired point within the focusing range of the apparatus. For example, with a suitable telescope a motion of twenty inches of the telescope will shift the point at which the beam is projected, a distance of 20 inches along the vertical path of the beam at the working area.

In order to maintain the beam focussed upon the surface of work which is irregular in height it is necessary to measure the distance from the surface of the work at the point where the beam is to impinge to the axis of the telescope 6 and from this measurement derive the position to which the telescope should be moved so that the beam will be focussed upon the surface of the work. Knowing beforehand the relationship between the focussed position of the beam and the position of the telescope along the track and by using a focusing probe or sensor which by means of a transducer determines the position of the work with respect to the horizontal axis of the telescope 6, and a servo amplifier acting upon motor 9, the telescope 6 may be continuously re-positioned so that the beam always remains focussed upon the work even though the work varies in height. The passage of the laser beam along the path 1 creates a potential hazard inasmuch as laser beams of a frequency outside the visible range may be used and an operator may inadvertently pass his arm across the beam and be badly burned. In order to prevent such an accident the protective device illustrated in Figure 2 has been devised. The motorised telescopic tubular shield 19 completely surrounds the beam along its vertical path from the mirror to the workpiece. The servo motor 20 and the screw 21 are used to adjust the length of the telescoping shield to suit the instantaneous variations in the work height. The analogue voltage, which represents the mirror to work distance, activates the servo motor 9 which drives the telescope and also is fed to the servo amplifier controlling the servo motor 20 for adjusting the telescoping shield 19 to avoid interference between the work and the end of the protective device.

The apparatus shown in Figure 1 in-

cludes means for translating the beam from the laser welding head for a predetermined distance along the desired path either to weld or to cut the material. The laser head incorporating the telescope with its slide, servo mechanism and track, rides upon a boom assembly 22 supported by a single support pedestal 23 within which are mounted the mirrors 3, 4 and 5. The boom assembly includes parallel beams 24 and 25 between which a motorised beam travel arrangement causes the laser head to move back and forth over a predetermined distance along a horizontal axis through the centre of the telescope 6. The laser beam can thus be caused to travel from left to right along the work 14 and either weld two workpieces together or cut the workpieces along a predetermined path, the laser beam being focussed on the surface or at any desired point in relation to the surface of the work as the beam traverses it.

The telescoping tubular shield (Figure 2) is continuously adjusted in length as the laser head moves from one side to the other so that no interference occurs between the work and the end of the shield.

The means for shielding the laser beam illustrated in Figure 2 is a tubular shield 19 comprising telescoping tubes through which the beam passes. The beam passes through a hole in the supporting plate 12 and onto the workpiece 14 upon which it has been focussed. The plate 12 through which one end of the smaller telescoping tube is fastened supports a proximity probe 10 which senses the surface of the workpiece 14 and by means of a feedback servo mechanism which includes motor 20, nut 11 and screw 21, connected at its lower end to the supporting plate 12, adjusts the overall length of the telescoping tube assembly as the height of the workpiece varies in order to maintain the supporting plate 12 at a fixed distance from the workpiece. Supported on plate 12 is gas nozzle 13 through which inert shielding gases are directed to the area which has been welded by the laser beam, in order to prevent oxidation of the surface of the workpiece along the welded joint. When the laser beam is utilized for cutting or drilling operations, gases which increase the laser cutting speed and cutting depth capability are brought to the area by means of nozzle 13.

Means may also be provided on the telescoping tubes to detect any distortion of the tubes or excess strain on them, while the machine is in operation which can occur if the tubing collides with the work due to mechanical failure of servo components or human error. Strain gauges mounted at suitable points on the protective structure detect any undue strain and through suitable control means interrupt the laser beam and stop the machine.

Figure 3 is a block diagram of a feedback control system which may be used to position the laser beam shield and telescope for changes in work height.

Signals from the work height or proximity probe 10 and from a work to telescope reference 26 are fed to a summing junction 29. If there is a difference between the two signals the servo amplifier 28 actuates the laser shield drive 27 so as to shorten or lengthen the shield and adjust the work distance reference 26 to an anlogue voltage which represents the new working distance. The new value of work distance reference voltage is summed with the telescope position reference voltage 30 at a summing junction 31 and the error amplified by a servo amplifier 32 which feeds the telescope drive 33 so as to move the telescope and its position reference in the appropriate direction until the error is reduced to zero.

Figure 4 illustrates another arrangement for moving the telescope in order to focus it onto the work and illustrates, schematically, how the telescope and associated mirrors may be moved along two axes which are mutually perpendicular to each other. The telescope 6 is shown supported by four bushings 41 on slides 38 so that it is free to move back and forth along the slide so as to focus the laser beam upon the work as the height of the workpiece varies at the point where the beam impinges. The telescope and slide 38 support assembly is, in turn, mounted by bushings 42 so that it is free to move along the Y axis on slides 39 and the slide 39 support assembly is mounted by bushings 43 so that it is movable along the X axis on slides 40. In this way, the laser beam can be focussed upon the work and be made to move along any desired path in order to perform a welding, cutting, or heating operation upon the workpiece. The laser beam 1 is projected from the laser source and reflected by mirrors 3, 4 and 5 onto a mirror 49 which is mounted on bearing 43, and is then projected to mirror 48 which is mounted on a carriage which moves along slides 39.

Figure 5 illustrates an embodiment wherein the telescope 6 is disposed vertically and is movable in the vertical direction in order to focus the beam upon the work. The telescope 6 is moved up or down by a motor 9 which rotates screw 8 threaded through a nut fixed to one of the telescope supports 35 which are guided in groove 36 formed in the support 34. The support 34 may in turn be movable by means (not shown) as in Figure 4, along one or two axes so that the beam may be caused to move along any desired path on the workpiece. The laser beam 1 passes through a

hole in the supporting member 34 and is reflected by mirror 5 down the centre of the telescope 6 and passes from there to the focal point at or near the surface of the work. The laser beam shield 19 completely surrounds the laser beam which would otherwise be exposed. Provision has also been made to protect personnel from injury which could be caused as a result of inadvertent damage to the protective means 19. Should the protective device 19 move so that it strikes the workpiece, it could be bent so that the beam would strike the protective device and thus endanger the operator. To avoid such an accident the tubular shield 19 is mounted as shown in Figure 5A by means of three bolts 44, springs 45, and washers 47 arranged symmetrically on the body of telescope 6. A sensing device 37 is mounted on the telescope body and is in contact with the flange 46 of the tubular shield. Should the tubing 19 strike the workpiece or any other interfering body, the flange, restrained only by the force exerted by the springs 45, would separate from the telescope and this displacement would be sensed by the sensing devices 37 which would generate a signal which would act upon suitable circuitry so as to halt the generation of the laser beam.

WHAT I CLAIM IS:—

1. Laser beam apparatus comprising lens means for focussing the laser beam, means for sensing the relative position of the lens means and the surface of a workpiece which, in use, is disposed in the path of the beam, means actuable by the sensing means to move the lens means and the surface of the workpiece relative to one another into a desired relative position and thereby to maintain the focus of the beam in a desired position relative to the workpiece, and means for preventing interception of the beam other than by the workpiece.

2. Laser beam apparatus comprising means for generating a laser beam, lens means for focussing the beam, means for moving the beam and a workpiece, which, in use, is disposed in the path of the beam, relative to one another to traverse the beam over the surface of the workpiece, control means for maintaining the surface of the workpiece and the lens means a predetermined distance apart and thereby to maintain the focus of the beam in a desired position relative to the workpiece and means for preventing interception of the beam other than by the workpiece.

3. Laser apparatus according to claim 1 or claim 2 in which the last mentioned means comprises a shield surrounding the beam and variable in length.

4. Laser apparatus according to claim 3 in which the shield comprises an assembly of telescoping tubes and which includes means for automatically adjusting the overall length of said tube assembly in proportion to the variation in distance between the lens and the workpiece surface.

5. Laser apparatus according to any one of the preceding claims including means for interrupting the laser beam when the last mentioned means is displaced from its normal position.

6. Laser beam apparatus constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

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1360380 COMPLETE SPECIFICATION

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Sheet 1

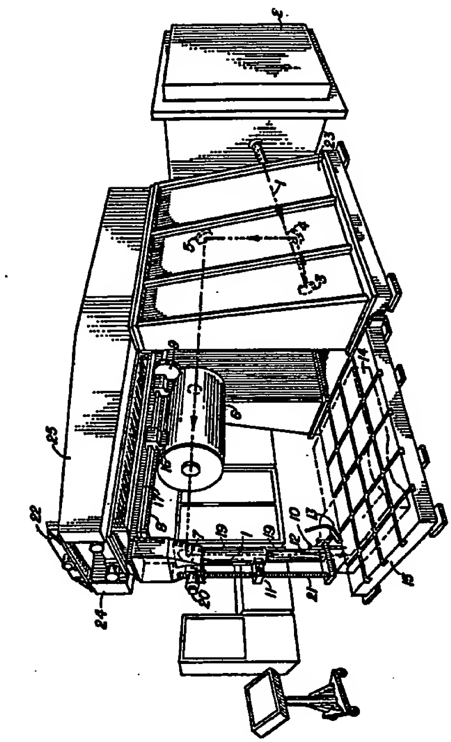

FIG. 1

1360380 COMPLETE SPECIFICATION

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Sheet 2

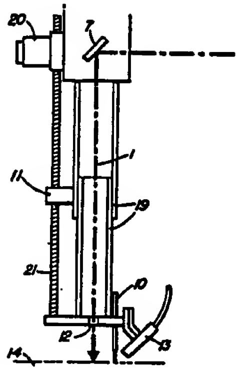

FIG. 2

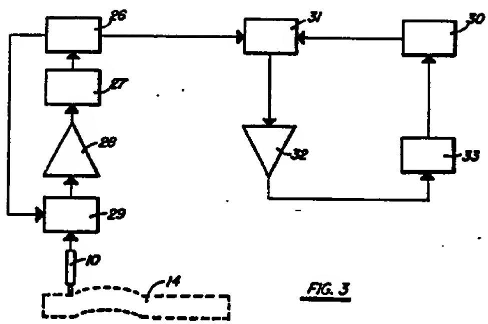

FIG. 3

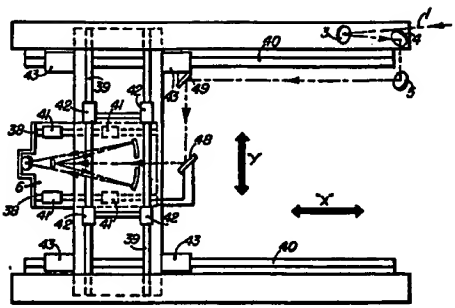

FIG. 4

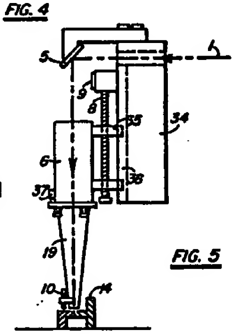

FIG. 5

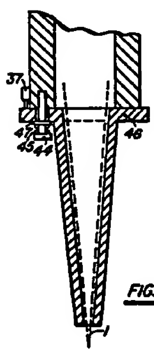

FIG. 5a